Real-Time Meteorological Battlespace Characterization in Support of Sea Power 21

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LONG-TERM GOALS

This project is a coordinated effort with the Naval Strike and Air Warfare Center (NSAWC) and the Naval Pacific Meteorology and Oceanography (METOC) Detachment (NPMOD) at Naval Air Station (NAS) Fallon, NV to create a shore test and development site to demonstrate enhanced weather support for strike warfare using a combination of the Naval Research Laboratory (NRL) Coupled Ocean/Atmosphere Mesoscale Prediction System – On Scene (COAMPS-OS®) and NOWCAST capabilities. The NOWCAST system is a network-centric data-fusion system that continuously updates a local environmental database with highly perishable, on-scene environmental data, accesses COAMPS-OS® model data, creates fused products to provide a consistent, integrated, web-enabled picture of the current, near real-time METOC impacts within the current operational context, and makes these relevant products available to end users via a web browser, allowing warfighters to automatically maintain a common situational awareness picture of the three-dimensional battlespace environment. This system will benefit the warfighter by providing a capability to help monitor and characterize the impact of rapidly changing, operationally significant weather situations that can be accessed directly over the Global Information Grid (GIG) by decision makers whenever they need to evaluate their missions for environmental dependencies within a common situational awareness framework. This commonality should help to improve coordination and efficiency on the battlefield.

OBJECTIVES

The specific objectives of this project are 1) to implement a combined COAMPS-OS and NOWCAST system in support of NAS Fallon; 2) to demonstrate enhanced real-time wind analysis capabilities by incorporating Through-The-Sensor (TTS) radar and Unmanned Aerial Vehicle (UAV) collected target area environmental data using data fusion and assimilation capabilities developed at NRL; and 3) to demonstrate the Rapid Environmental Assessment (REA) capability using the Supplemental Weather Radar (SWR) and UAV assets at Fallon, NV in coordination with NPMOD Fallon and with the cooperation of the Fleet Numerical Meteorology and Oceanography Center (FNMOC).

The three-year demonstration (FY04 - FY06) of real-time automated NOWCAST and forecast products for Fallon has provided additional support to NPMOD Fallon for Strike Warfare (STW)

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training beyond the support traditionally provided. Warfighter (pilots, squadron commanders, air traffic control specialists, STW planners, and operational METOC specialists) comments within a focused Integrated Product Team (IPT) provided valuable feedback to improve the automated system; verification and validation data collected has helped to scientifically evaluate the value added by NOWCAST to traditional human-intensive STW forecasting techniques.

APPROACH

COAMPS-OS and NOWCAST have been integrated into a single computer system installed at NRL Monterey with network access provided to NPMOD Fallon in a reach-back mode of operation. Automated products from the combined system are available over the network where they have been interfaced with NSAWC training operations through weather briefs provided by NPMOD Fallon and through a dedicated large screen (50") display located within the Strike Operations Center (SOC). Although NSAWC is located at Fallon in large part because of the high percentage of "good days for flying" weather, the area does experience hazardous and challenging weather with winter storms and related flight icing conditions, occasional summer thunderstorms, ceiling and visibility restrictions, and strong surface winds, including blowing dust, which varies valley-to-valley. Despite the good weather, NOWCAST was implemented where the warfighter trains as a way of exposing a capability that may eventually transition to operations. While introducing warfighters to advanced R&D capabilities, NOWCAST development was "fine-tuned" by working with NPMOD Fallon and NSAWC.

To provide data for the system, an operational Tactical Environmental Database System (TEDS) database was installed with a data feed of model grids and conventional observations from FNMOC. A data interface was developed for the local Supplemental Weather Radar (SWR), an Enterprise Inc. Doppler weather radar implemented by SPAWAR. The local SWR data has been integrated with NOAA Next Generation Weather Radar (NEXRAD) data available from the Reno, Elko, and other nearby NEXRAD radar sites.

To supplement the data provided by the radars and FNMOC, the Desert Research Institute (DRI), Reno, NV purchased and installed four automated surface sensors suites, forming a local range sensor network. The automated surface observations provide verification of NOWCAST products and improved NPMOD Fallon's awareness of conditions out in the range, where complex terrain influences the wind flow and mesoscale variations in thunderstorms and winter storms make accurate forecasting and assessment of the "weather on target" difficult.

In addition to the NSAWC component, a data interface was also developed and tested for the SPS-48 radar to add value to the TTS data suite for wind and hazardous weather products produced by NOWCAST. SPAWAR is developing the Doppler weather radar capability for the SPS-48 radar onboard all carriers. Although a real-time feed of SPS-48 data was not yet available, SPAWAR provided test data sets for development and we envision that this project will be ready in the out-years to provide a valuable contribution to NOWCAST.

WORK COMPLETED

A Linux cluster computer system was provided by NRL and dedicated to running both COAMPS-OS and NOWCAST, including the TEDS database and satellite and radar data processing. In coordination with NPMOD Fallon, specific domains have been set up and are running for both COAMPS® and NOWCAST. As shown in Figure 1, geographic overlays for the specific ranges at Fallon have been

added to the system for enhanced displays and the software and connectivity have been tested with NMCI terminals at Fallon.

Radar data is one of the major components of the NOWCAST system and played an important role during the Fallon demonstration. Real-time data from the SWR, operated NPMOD Fallon, along with thirteen NEXRAD radars in the surrounding area, were processed, quality controlled, and fused with other sensor data to provide near real-time 2D and 3D products every 10 minutes for nowcasting high-impact weather for NSAWC operations.

NRL worked closely with NPMOD Fallon to re-configure the SWR and transfer the real-time radar data to NRL Monterey for processing. In collaboration with scientists at the National Center for Atmospheric Research (NCAR), University of Oklahoma (OU) and National Severe Storms Laboratory (NSSL), and Massachusetts Institute of Technology Lincoln Lab (MIT/LL), new algorithms suitable for processing and quality control of DoD radar data have been developed, tested and applied to the SWR data. In addition, a site-specific normal propagation ground clutter removal method for real-time use with the SWR radar data was designed and implemented. As a result, the extensive radar echoes from the mountain ranges around Fallon were removed in the radar images displayed on NOWCAST. Algorithms and software have also been adapted and improved for generating NOWCAST products from the SWR data alone. These products include composite reflectivity (both single radar and mosaic), 3D reflectivity mosaic, single radar radial velocity, and Velocity Azimuth Display (VAD) wind profiles. Meanwhile, the quality controlled level-II (3D) data from SWR were also fused with other sensor data for 3D wind and cloud analysis.

The NRL 3D Reflectivity Mosaic system was recently developed at NRL Monterey. The system processes reflectivity data from one or more radars in an area of interest, and then optimally interpolates these data from the radar native semi-spherical coordinates to a common 3D grid for easy application to storm studies, model verification and data assimilation. The system is globally re-locatable and automatically adapts to use any 3D grid, domain size and grid resolution, and is therefore suitable for military use and field experiments. The system is currently used to generate 3D reflectivity mosaics every 10 minutes with data from the SWR and the 13 NEXRAD radars, and the products are then used as inputs to the NCAR Thunderstorm Identification, Tracking, Analysis and Nowcasting (TITAN) system for storm nowcasting for the Fallon area. In collaboration with NCAR, TITAN was implemented into NOWCAST and has successfully demonstrated its usefulness in storm nowcasting. The system is running over the Fallon area with the input of 3D radar reflectivity data from the 3D Reflectivity Mosaic and produces 30 min., 1 h and 2 h storm predictions every 10 min.

A three-dimensional cloud analysis system originally developed at NOAA's Global System Division (formerly the Forecast Systems Laboratory or FSL) as a part of the Local Analysis and Prediction System (LAPS) and later modified by OU as a part of the ARPS Data Assimilation System (ADAS), was adapted and integrated into COAMPS-OS for 3D cloud analysis and nowcasting. The system fuses data from geostationary satellites, radars and surface observations, using COAMPS-OS forecasts as background fields, to produce 3D fields of cloud liquid water, cloud ice, rain water, snow and graupel. The system is running hourly over the Fallon area and provides 3D cloud fields that are then used by NOWCAST to generate products such as cloud fraction, ceiling and visibility.

Efforts were coordinated with the Desert Research Institute (DRI) to research, acquire, install, and operate four surface weather sensors at designated locations throughout the Fallon range complex. The chosen locations were the three active bombing target ranges, Bravo 17, 19, and 20, and in a prominent

North/South valley electronic warfare training range, EW-71. The stations record a suite of environmental data including surface temperature, dew point, winds, pressure, insolation, precipitation, and visibility and ceiling height (Bravo 17 only). The data is relayed via satellite uplink to DRI where they are integrated with the MesoWest data network. NOWCAST incorporates the data by downloading it from the MesoWest web site.

Acquiring and incorporating near real-time in-situ data is an incredibly important feature in the development of NOWCAST and has greatly increased the value and usability of the system. Adding four surface observation stations to an extremely data sparse area influenced by complex terrain has significantly aided forecasters and warfighters in planning, altering, and deciding to cancel expensive exercises. NOWCAST was also enhanced to display aircraft meteorological observations collected in flight, including those from Unmanned Aerial Systems (UAS). UAS data are increasingly available from training flights and are an important source of information in data-denied operational theaters.

Based on user feedback at Fallon, and in coordination with the USS NIMITZ, several new products have been added to improve the Fallon NOWCAST system. We developed a suite of "lite" products that consist of scripted NOWCAST animated products automatically produced and accessible on an open web page. Although these products are not user-configurable, they are easier to access via NMCI and IT-21 and are easily incorporated into PowerPoint briefs. These products are shown in Figure 2 and they are continuously updated and displayed in a simple animation loop on the dedicated large-screen display in the NSAWC SOC.

The quality of COAMPS surface forecasts of temperature and winds were scored (using root mean square error (RMS), bias, confidence interval) using hourly observation reports from NAS Fallon, Bravo 17, 19, and 20. Software was developed that would download the sensor data from the DRI web site and ingest it into the local TEDS. Once in TEDS, this sensor data was treated the same as other surface data: the data was available for display, verification, and analysis/assimilation. An example for Bravo 17 is shown in Figure 3 that demonstrates the dynamic automatic bias correction (mean: -3.07) and time phase shift guidance (First Guess adjusted –2 hr) made possible by the DRI site data. The "Adjusted Forecasts" shown in Figure 2 use the station observations to improve forecast accuracy by as much as 40%. The confidence gained by users consulting the scores at these sites assured the forecasters and planners that the COAMPS surface wind forecasts out in the Fallon range were reliable and should be heeded to avoid potentially hazardous conditions. Similar confidence gained in the forecast of cloud layers significantly aided the daily planning of training missions.

RESULTS

The Fallon COAMPS-OS/NOWCAST system fuses a wide variety of data types and provides a single geo-rectified web-based display that easily replaces many dedicated screens. Radar data from the local SWR and NEXRAD have been assimilated into high resolution products that provide impacts for NSAWC aircraft operations. The interaction with the warfighters has reinforced their priorities for data fusion and decision-enabling products and has resulted in several new product lines and interfaces. New products were created to provide cloud layer, visibility, and winds for training areas. Through direct interaction with NPMOD Fallon, we find a continuing need for NOWCAST to supplement existing METOC forecast assets with an automated capability to continuously assimilate, fuse, and display data from all available sources including conventional surface observations, satellite, radar, and "through-the-sensor" observations including unmanned platforms.

With developing and deploying NOWCAST into the operational forecasting environment at NPMOD Fallon it became increasingly clear that there were two hurdles proving to be serious obstacles. First, with the delay of installing an unclassified-to-classified network data pump, potential users of NOWCAST at NSAWC would never get a chance to interact with the system firsthand. Second, despite the training with NOWCAST and visits to NPMOD, forecasters were not using the capability. To comply with network mandates, user authentication was required to load the software. Furthermore, because NOWCAST requires current versions of Java, only the S&T NCMI seats have the appropriate software configuration to run the full NOWCAST interface. Taking into account these impediments, a new approach needed to be developed.

NOWCAST developers learned the general steps of air warfare training operations at NSAWC and worked with aviators and operational decision makers to develop a simple suite of automated products displayed in a fashion that would prove instrumental in planning and coordinating training missions. A large format flat screen monitor and accompanying computer were purchased for display directly in the SOC, solely dedicated to the broadcast of animating weather forecast products tailored to the warfighters' specific needs. The product suite is hosted on a web server at NRL Monterey. The suite includes short animations of the following products for 0, 1, and 2 hours in the future, for a limited domain covering the extent of, and highlighting specific operational locations within, the Fallon Range Training Complex: surface visibility (displayed in text in statute miles), surface winds (colored vectors in knots that vary as specific safety thresholds are breached), cloud layers (displayed in text as cloud type in hundreds of feet) and vertical cloud cross-sections across the four main bombing ranges and across NAS Fallon itself, that depict physical representations of the presence of clouds. The cloud cross-section products also include a winds aloft profile, helpful for determining which target ranges to use for certain strike missions. Furthermore, two additional history-to-real-time (no forecasts) products round out the suite: infrared satellite and composite radar reflectivity (Fallon SWR and the Reno and Elko NEXRADs). Both of these products also overlay the station observations from area surface stations and the four DRI surface stations installed in the range complex. As expected, the addition of the verification data facilitated the quantitative assessment of NOWCAST products that resulted in confidence by the end users to value the products.

IMPACT/APPLICATIONS

The technology being implemented and tested at Fallon is the focus of a telescoping strategy to provide automated environmental products tailored to the decision-making needs of the warfighter, from global scales down to tactical scales in both time and space, within the emerging Command and Control framework of the Global Information Grid (GIG). In particular, NOWCAST represents a paradigm shift from periodic products that are briefed and interpreted by METOC personnel to nearly continuous products that are automatically produced without human intervention, easily accessible over the web and automatically updated, tailored for interpretation directly by the warfighter, and automatically and continuously verified using available data in a "self assessment" that provides valuable confidence information to the decision maker. NOWCAST enhances the role of METOC support by supplementing the existing labor intensive forecast capability with continuous, automated, short-term (less than 2 hours) decision-enabling products, thus freeing the forecaster to concentrate on the longer-range projections for planning and evaluation purposes.

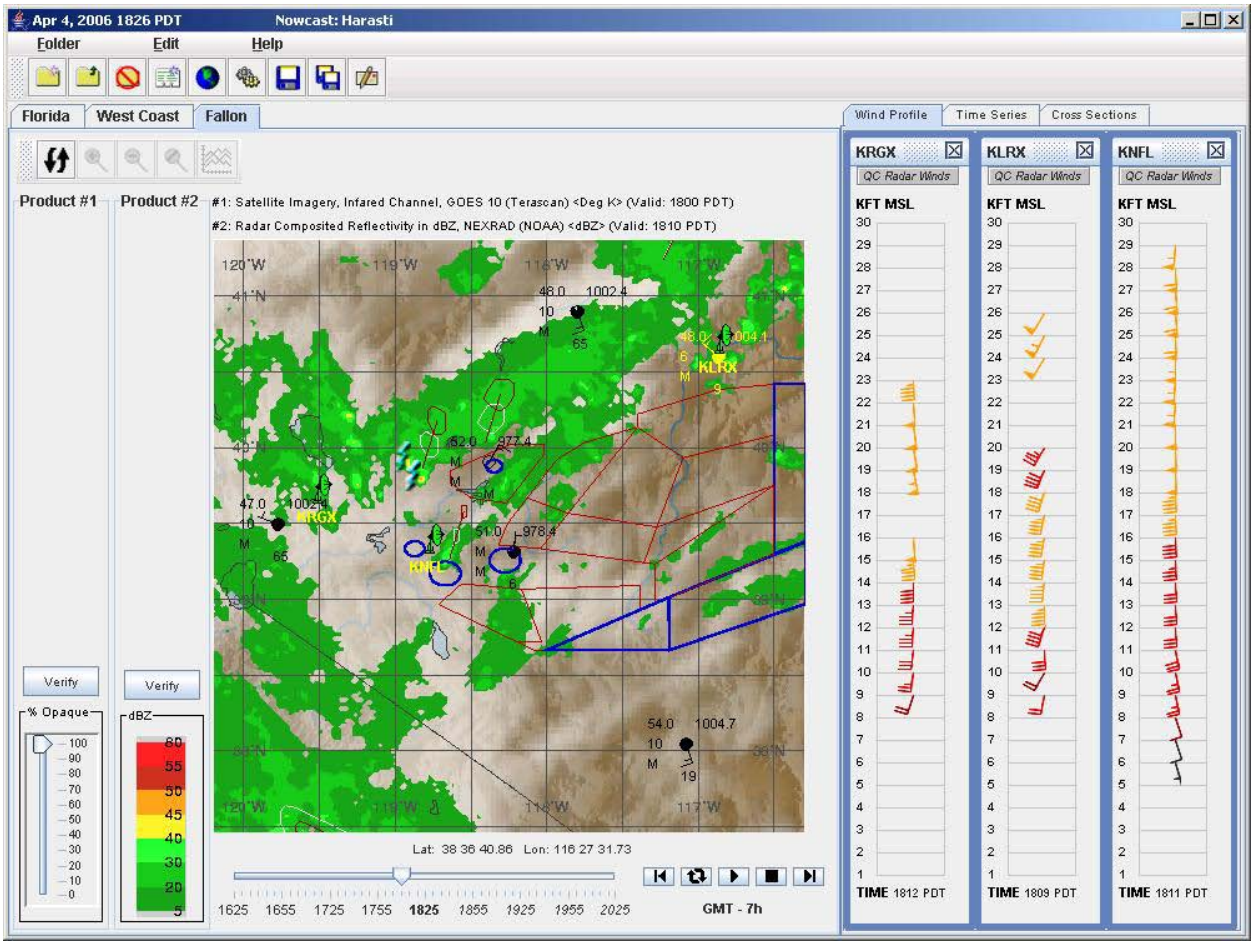

Figure 1. The NOWCAST user interface showing the geo-rectified fusion of products over the Fallon domain. This display was developed to alleviate the user from the burden of having to look at five different displays to see five different types of weather data. A map of the Fallon operational areas is shown with infrared satellite imagery of the clouds in white in the background. The composite radar reflectivity data of the precipitation is overlaid in green, which includes the quality-controlled mosaic SWR data from Fallon (KNFL) along with nearby NEXRAD data from Reno (KRGX) and Elko (KLRX), NV. The upper rainband shows 30- and 60-min. TITAN storm cell (with reflectivity > 25 dBZ) forecasts with the white and black polygons, respectively, with a black line leading back to the originating cell, along with the location of embedded lightning strikes. The right panel shows VAD wind profiles calculated from the radial velocity data of these three radars and color-coded by wind speed. The KRGX and KLRX VAD winds are provided by a feed from the NEXRAD Level III data network whereas the KNFL VAD winds were calculated by NOWCAST from the SWR radial velocity full-resolution (i.e., Level II-like) data using an enhanced-QC NRL VAD wind algorithm.

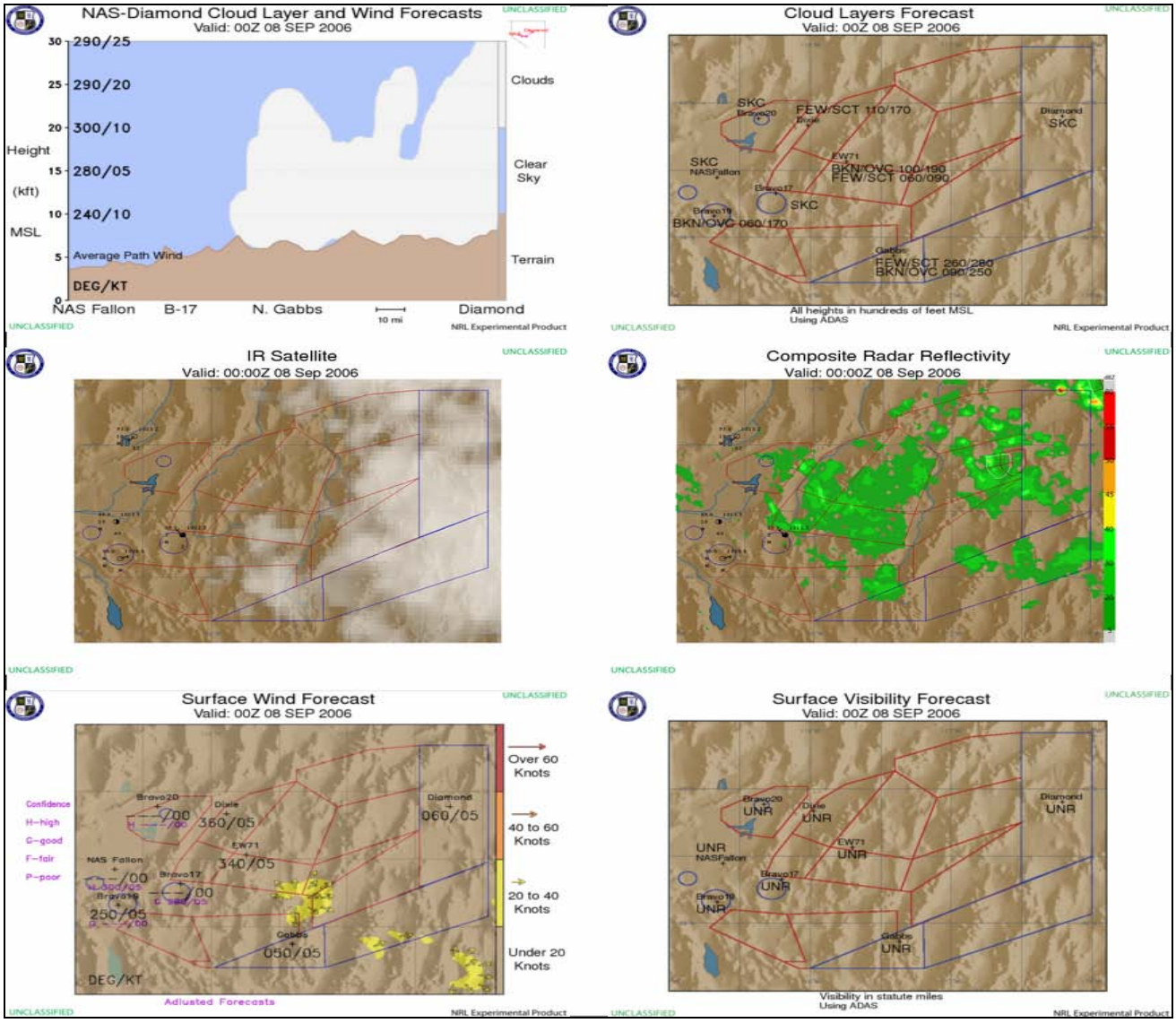

Figure 2. A mosaic showing six of the NOWCAST products developed for NSAWC. Clockwise from upper-left: the Cloud Layer and Winds Forecast product from COAMPS shows clouds and winds aloft profiles along a fixed cross section from the NAS Fallon air field to the Diamond area where exercises frequently originate their battle maneuvers. In this case, COAMPS is forecasting thunderstorm development in excess of 30,000 ft; the Cloud Layers Forecast product displays cloud layer information over the operational domain summarized for selected areas in ASCII text coded format relevant to pilots; the Composite Radar Reflectivity product shows areas of precipitation derived from the Doppler Radar Reflectivity Mosaic; the Surface Visibility Forecast product shows in ASCII text code the COAMPS forecasts for horizontal visibility at the surface; the Surface Wind Forecast products shows the COAMPS forecasts for 10 m winds in ASCII text code overlaid on a tri-color graphic highlighting areas of winds greater than 20 kt and showing direction arrows. In this case COAMPS is forecasting surface radial wind patterns due to outflow boundaries from the developing thunderstorms; the IR (Infrared)satellite images shows the observed cloud top temperature using a grey scale with white being the coldest (highest) cloud. In this example, the areal extent of the observed cloud field compares favorably with the COAMPS cloud forecast (shown above).

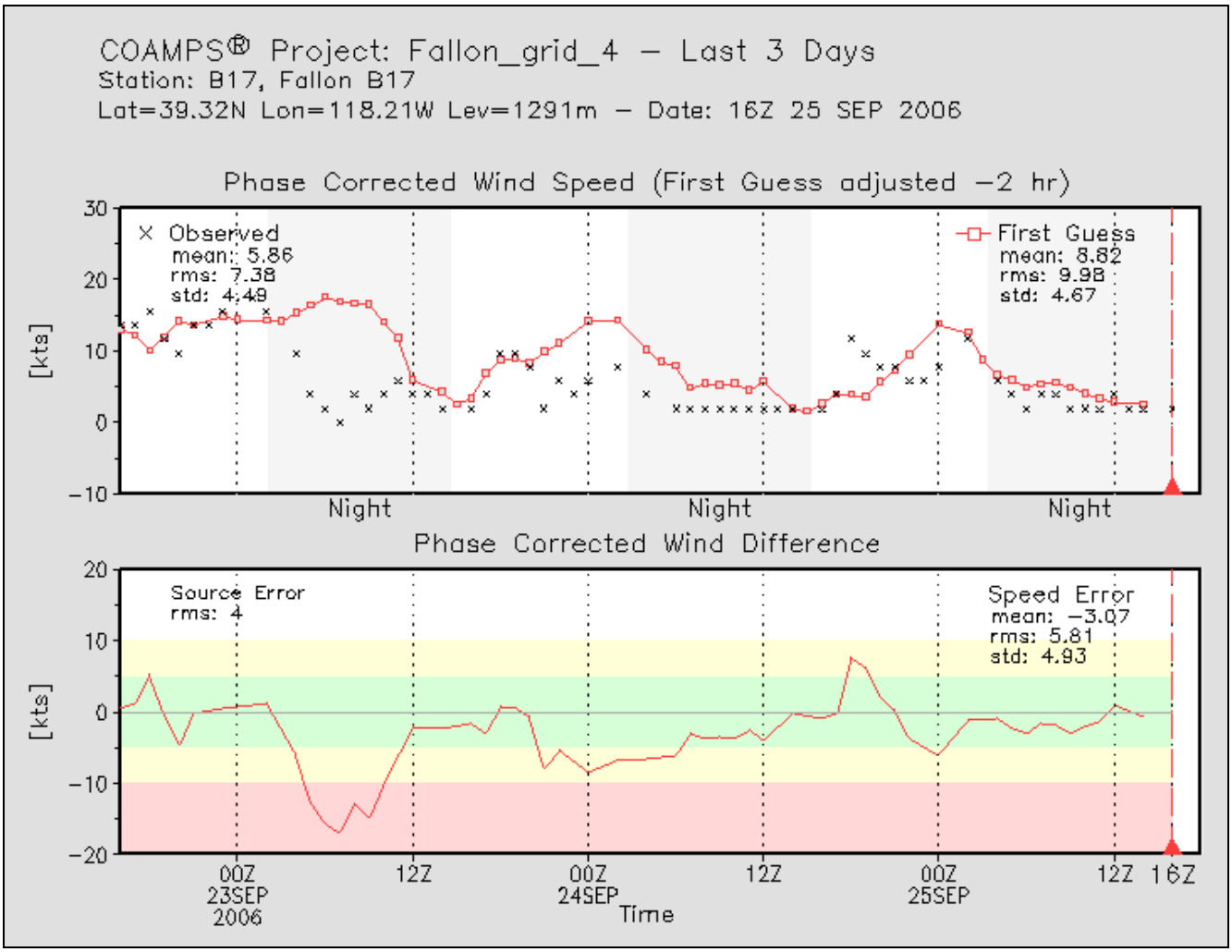

Figure 3. A time series history of surface winds, both observed and forecast, at Bravo 17 with the forecast values dynamically offset -2 hours to maximize their correlation with observed wind. This re-correlation of the forecast provides an improved wind estimate quoted in the lower time series as a –3.07 knot residual model bias which is due to local effects. Since the time offset and bias are observed to have a consistent behavior, they are valuable in helping the forecaster improve the wind forecasts at Fallon.

RELATED PROJECTS

This RTP has a companion 6.4 project supported by the Oceanographer of the Navy (N84) (PE 0603207N X2342). In addition, the ONR project for Shipboard Data Assimilation System development (N0001406WX20243) and the NRL Base Optimum Use of DoD Radar in Battlespace Environmental Prediction project, and a similar SPAWAR Systems Center project using the SPS-48 radar have been important to this project. NOWCAST system development was sponsored by ONR in FY 2000-2005 (N001405WX20413).

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